A Spatial-Temporal Model of Rhinoceros Extinction in China

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Abstract In this paper we determined the northern boundaries of rhinoceros distribution in different historic stages base on our previous study results of rhinoceros extinction process in China. With Logistic equation, the environmental carrying capacity was explored and a spatial-temporal model for rhinoceros extinction was established.

Key words: Rhinoceros, Extinction, Model, China.

Introduction

Three thousand years ago, wild rhinoceros (*Rhinoceros unicornis*, *R. sondaicus* and *Dicerorhinus sumatrensis*) lived in the vast area of China, the northern distribution boundary was more than 1800 km along Yellow River. With the increase of human population pressure, the habitats of rhinoceros shrank continuously and extinction occurred in Yunnan in early 20th century[1].

The long-term historical documents on the changes of rhinoceros distribution in China are unique in the world. It is 3400~3200 years ago (about 1400~1200 BC, Shang Dynasty) that rhinoceros was described by pictographs on bones (Fig. 1)[2]. The plenty information in ancient Chinese books provided us an opportunity to get more knowledge of the ecological principles about rhinoceros extinction in China.

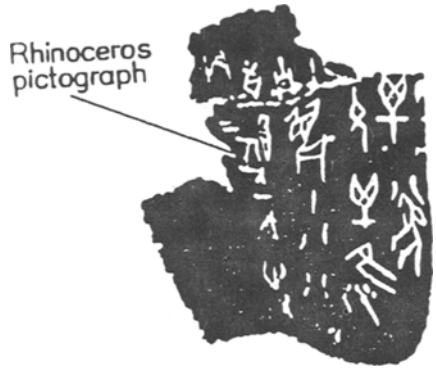

Fig. 1 Pictographs on bones about 3400~3200 years ago (Shang Dynasty),
indicating a king captured a rhinoceros

In another paper[1], we made a systematical analysis on the historical process of rhinoceros extinction and the relationship with human population pressure in China, and got the threshold value of human population for rhinoceros survival. In this paper, we give the detailed changes of the northern boundaries of rhinoceros distribution in different historical stages; based on Logistic equation, the authors build a spatial-temporal model of rhinoceros extinction in China.

On The Environmental Carrying Capacity *K*

The Logistic equation expresses profoundly the essential relation between population number *N* and environmental carrying capacity *K*:

$$\frac{DN}{Dt} = rN_0(1-\frac{N}{K}) \quad (1)$$

and

$$N_t = \frac{K}{(1+e^{\alpha - rt})} \quad (2)$$

where, *r* is the intrinsic increase rate of population, t time; N_0 and N_t are population numbers at starting time and ending time respectively; α is a constant related to population characteristics.

Since the report by Elton on cyclic fluctuations in small rodent populations[3], there have been extensive studies on how *K* changes with time. *K* is not a constant, but a variable flickering around an equilibrium value. It is better to say $K=K_{(t)}$.

At present, the environmental conditions for most biotic populations seriously deteriorate. The size and quality of the existing area are all changing, hence $K_{(t)}$ changes accordingly to the variation in the population area *S*: $K=K_{(t,\ s)}$

Let us take *S* to measure area, *S* is the rhinoceros' maximum living area and unit area S_0 has a carrying capacity δ_0. Thus, $K_{(t,\ s)} = \delta_0 S_t$. When the area is

gradually deteriorating (or its character is changing), then $S=S_{(t)}$ or $S=S_{(\delta, t)}$, and $K_{(t, s)}= \delta_0 S_{(\delta, t)}$.. When $S_{(t)} \rightarrow 0$, the population tends to decrease and finally may become extinct.

The *rhinoceros* population in China experienced such a process. Under the increasing human population pressure, rhinoceros lost gradually the original habitats and got extinct.

Northern Boundaries of Rhinoceros Distribution in Different Historic Times of China

According to our previous study results[1], here we can obtain the northern boundaries of rhinoceros distribution in different historic stages (Fig. 2). The recent 3200 years of the Chinese history are divided into eight periods, each lasting about 400 years. The area with rhinoceros contracted southward. However the rhinoceros in the eastern coastal area withdrew at a higher rate than in the central mountain area. This process was simultaneous to the spread of Chinese population. At last rhinoceros vanished at the west of Yunnan about 200 years ago.

Fig. 2. The historical change in northern boundary lines of rhinoceros distribution in China

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Suppose, the maximal living area of rhinoceros (in Shang Dynasty) was S_0, and the rhinoceros density per unit area δ_0 was constant. The rhinoceros existent area changed from S_0 to $S_{(t)}$ during 3200 years, and $S_{(t)} \leq S_0$. Hence, on the average:

$a=1/T$, $T=t_0-t_{(s=0)}$

where, t_0 and $t_{(s=0)}$ the starting time and ending time for the model. Therefore: $a=1/(3200-200)=3.33\times10^{-4}$, the annual decrease of rhinoceros living area is $a \cdot S_0$. At time t, the remaining habitats for rhinoceros $S_{(t)}= S_0-aS_0t$.

Consequently:

$$K_{(t,s)} = \delta_0 S_{(t)} = (1-at)\delta_0 S_0 \quad (3)$$

$$N_{(t,s)} = \frac{K_{(t,s)}}{(1+e^{\alpha \cdot rt})} = \frac{(1-at)\delta_0 S_0}{(1+e^{\alpha \cdot rt})} \quad (4)$$

Once the estimates of necessary parameters are provided, we can use this model to get the spatial and temporal distribution of rhinoceros at different times, as well as the extinction moment.

Discussion

The parameter r, i.e. the intrinsic increase rate of rhinoceros population, is assumed to be constant within the recent more than 3000 years. It means rhinoceros extinction wasn't because of the population itself. Some scholars took climatic factors as the cause of rhinoceros extinction[4], but it is unreasonable. If climatic alteration brought about the extinction, the vanishing speed of rhinoceros in the eastern coastal zone would be slower than in the central mountain area. But this is not the case.

From the model built above, we can see that the decrease of the carrying capacity for rhinoceros should be attributed to man-made destruction. The real reason for the extinction was the shrinkage of rhinoceros habitats due to spreading of human population. Human populations are expelling other biotic populations from their original habitats, So we must put more emphasis on this fact.

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